



DRIVE
SYSTEM
DESIGN



Gearing Up for Lower Cost Electric Drives

Novel Methods for Analysing Integrated Electric Powertrains

The 6th International Electric vehicle Expo – 9th May 2019

Lee M. Sykes

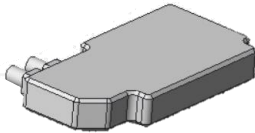
www.drivesystemdesign.com



Component trade-offs affecting system cost and efficiency

Increased motor speed

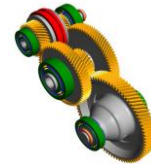
Inverter



Motor



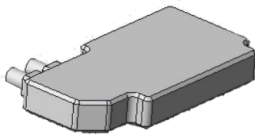
Transmission



Component trade-offs affecting system cost and efficiency

Increased motor speed

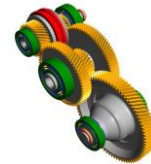
Inverter



Motor



Transmission



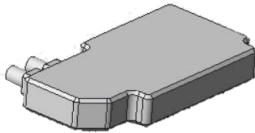
Reduced cost ✓□

Reduced Mass ✓□

Component trade-offs affecting system cost and efficiency

Increased motor speed

Inverter



Increased cost



Reduced
Efficiency



Motor



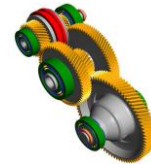
Reduced cost



Reduced Mass



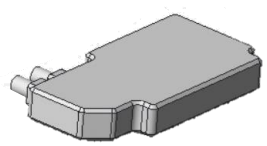
Transmission



Component trade-offs affecting system cost and efficiency

Increased motor speed

Inverter



- Increased cost ☒
- Reduced Efficiency ☒

Motor



- Reduced cost ☒
- Reduced Mass ☒

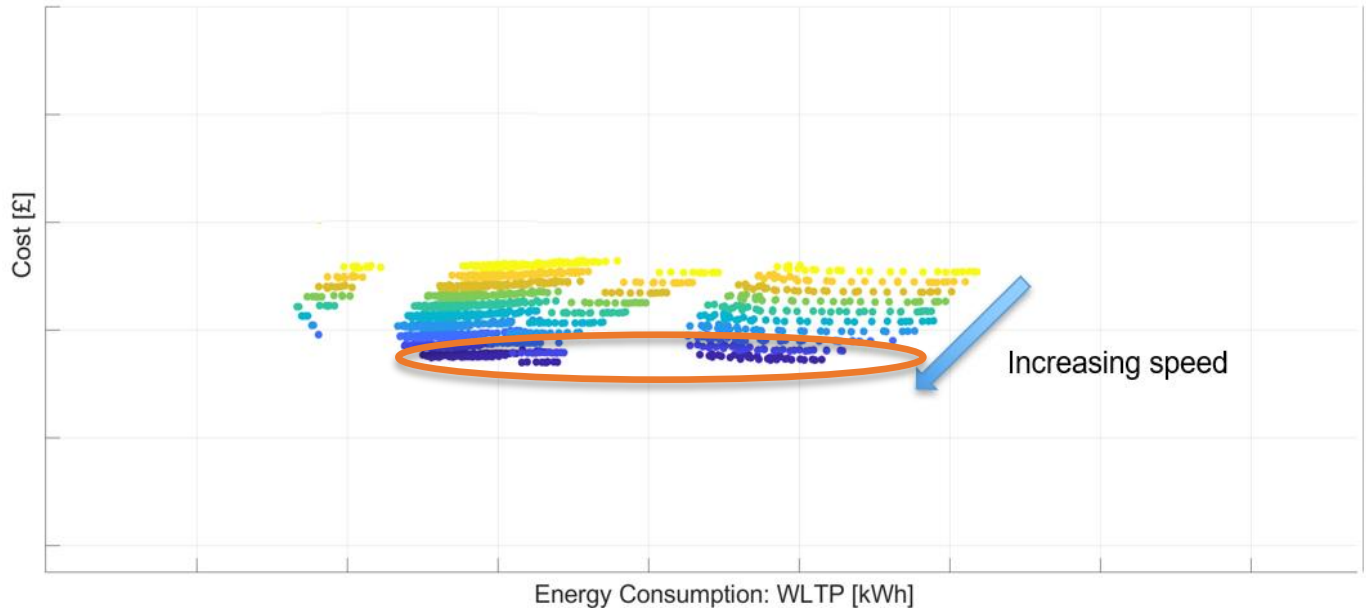
Transmission



- Increased cost ☒
- Reduced Efficiency ☒

Component trade-offs affecting system cost and efficiency

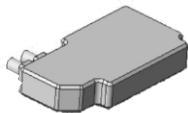
Cost against energy consumption



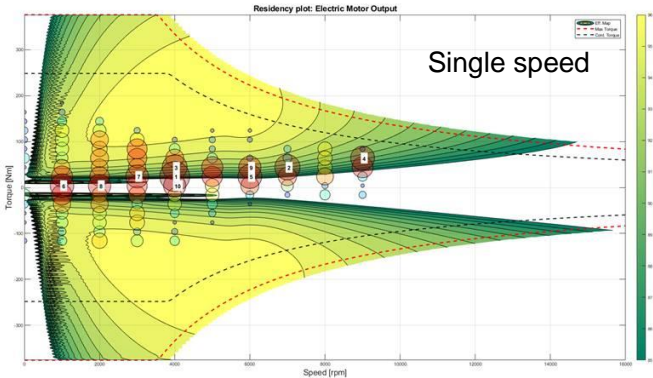
Component trade-offs affecting system cost and efficiency

Single / Multi speed transmission

Inverter



Motor



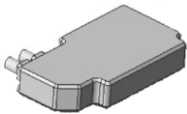
Transmission



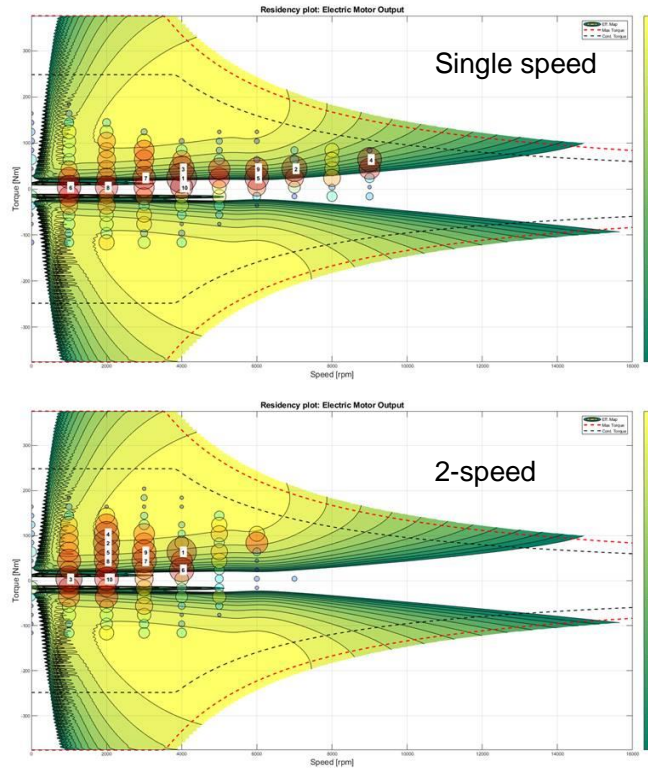
Component trade-offs affecting system cost and efficiency

Single / Multi speed transmission

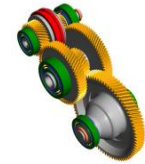
Inverter



Motor



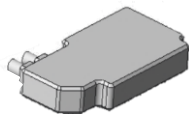
Transmission



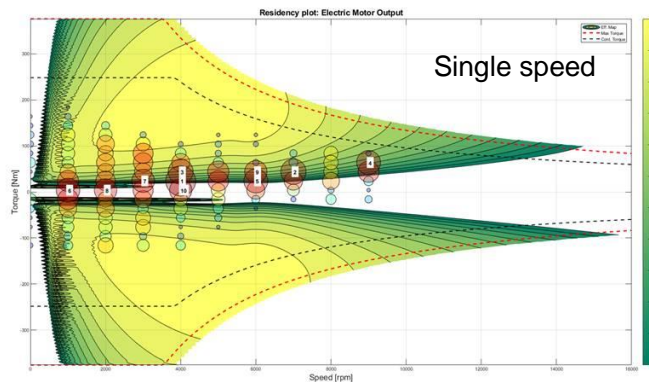
Component trade-offs affecting system cost and efficiency

Single / Multi speed transmission

Inverter



Motor



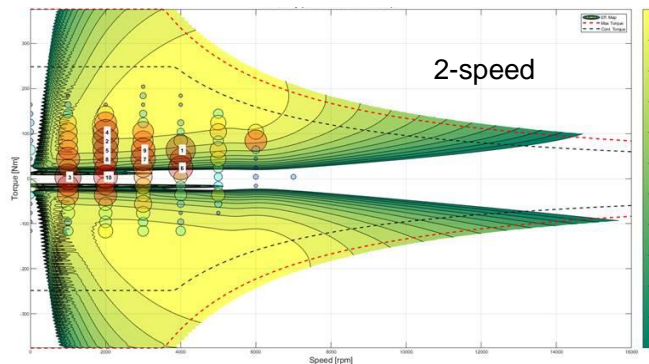
Transmission



Reduced Switching Frequency



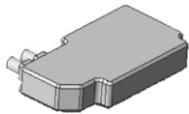
Reduced switching loss



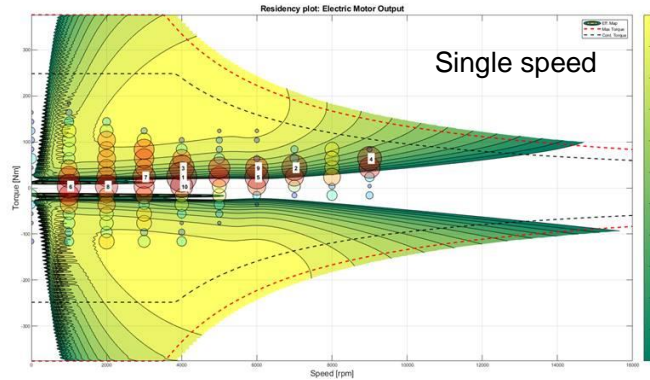
Component trade-offs affecting system cost and efficiency

Single / Multi speed transmission

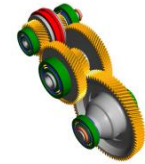
Inverter



Motor



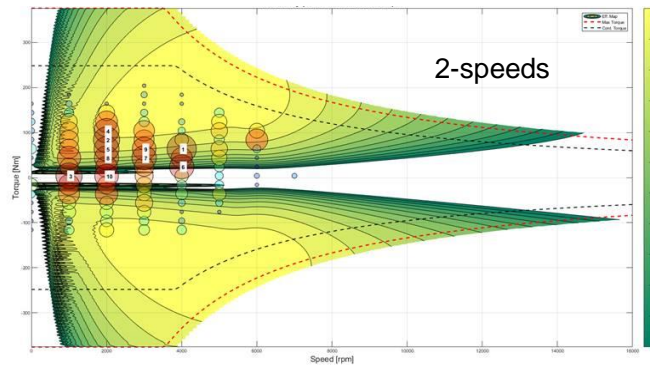
Transmission



Reduced Switching Frequency



Reduced switching loss



Increased cost



Reduced Efficiency



Component trade-offs affecting system cost and efficiency

Effect of motor current on inverter

Motor



Increased motor current

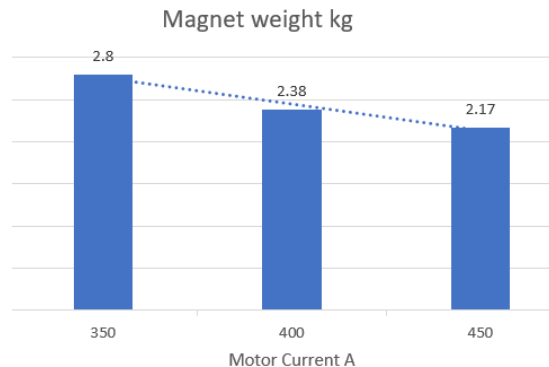
Reduced cost ✓□

Reduced magnet volume ✓□

Component trade-offs affecting system cost and efficiency

Effect of motor current on inverter

Motor



Increased motor current

Reduced cost ✓

Reduced magnet volume ✓

Component trade-offs affecting system cost and efficiency

Effect of motor current on inverter

Motor

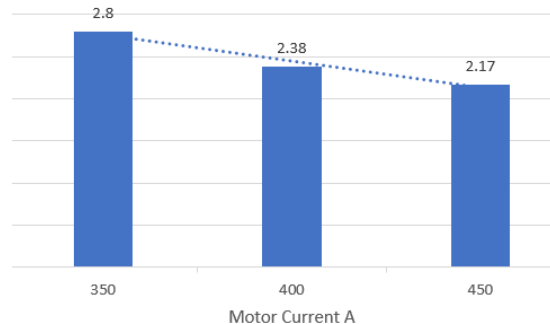


Increased motor current

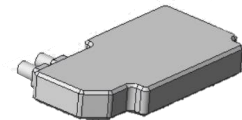
Reduced cost ☒

Reduced magnet volume ☒

Magnet weight kg



Inverter



Increased cost

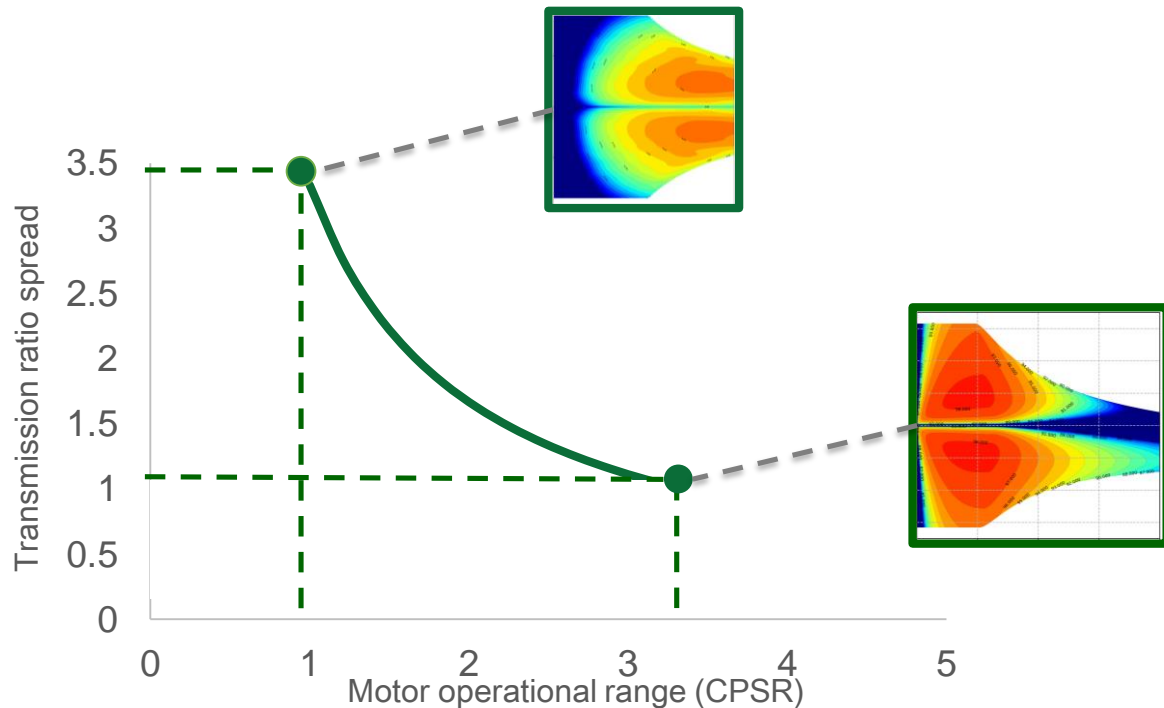


Reduced efficiency



Component trade-offs affecting system cost and efficiency

Effect of motor type on transmission matching



Optimise an EV powertrain system as a whole

Opportunities

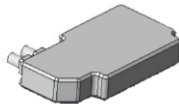


Optimised speed / gear ratio

Optimal topology

Optimised current

Type



IGBT and SiC

Switching strategy

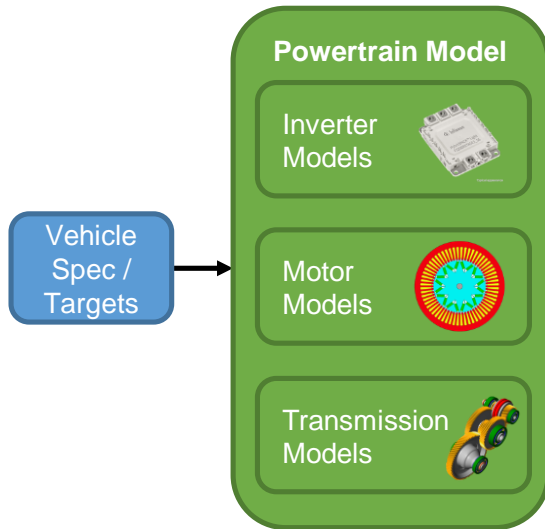


Single / multi speeds

Different types / configurations

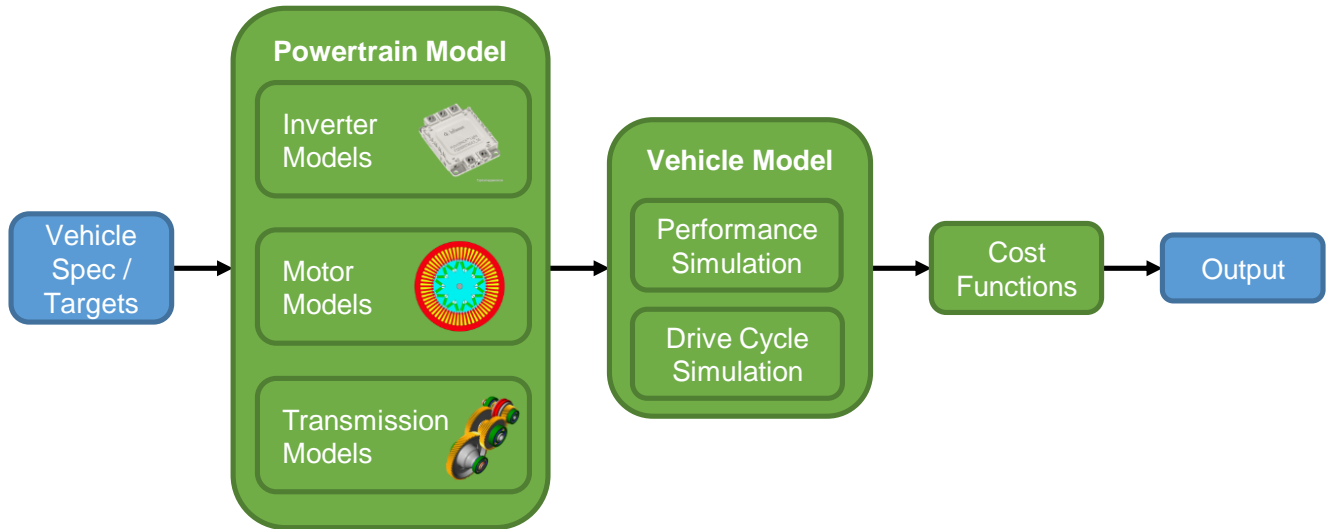
What is the DSD process?

1,000s of powertrain variants



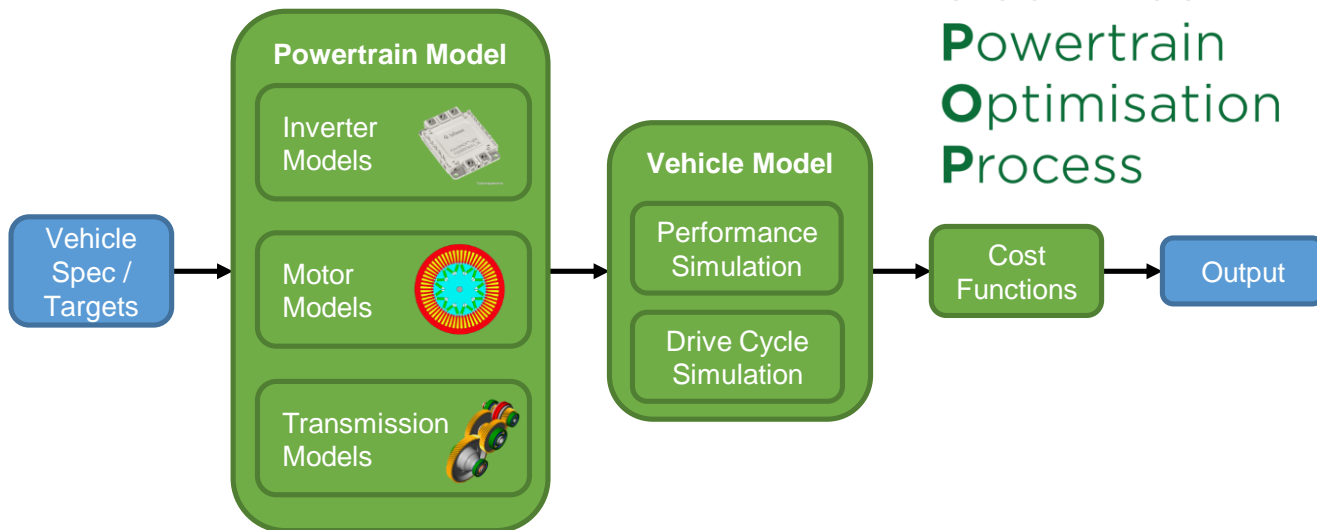
What is the DSD process?

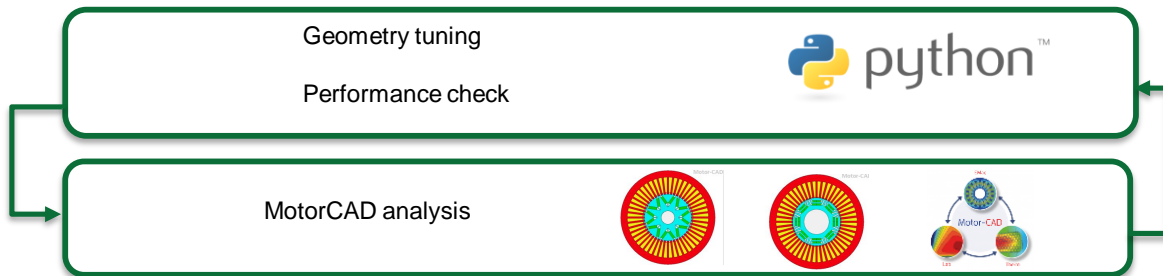
1,000s of powertrain variants

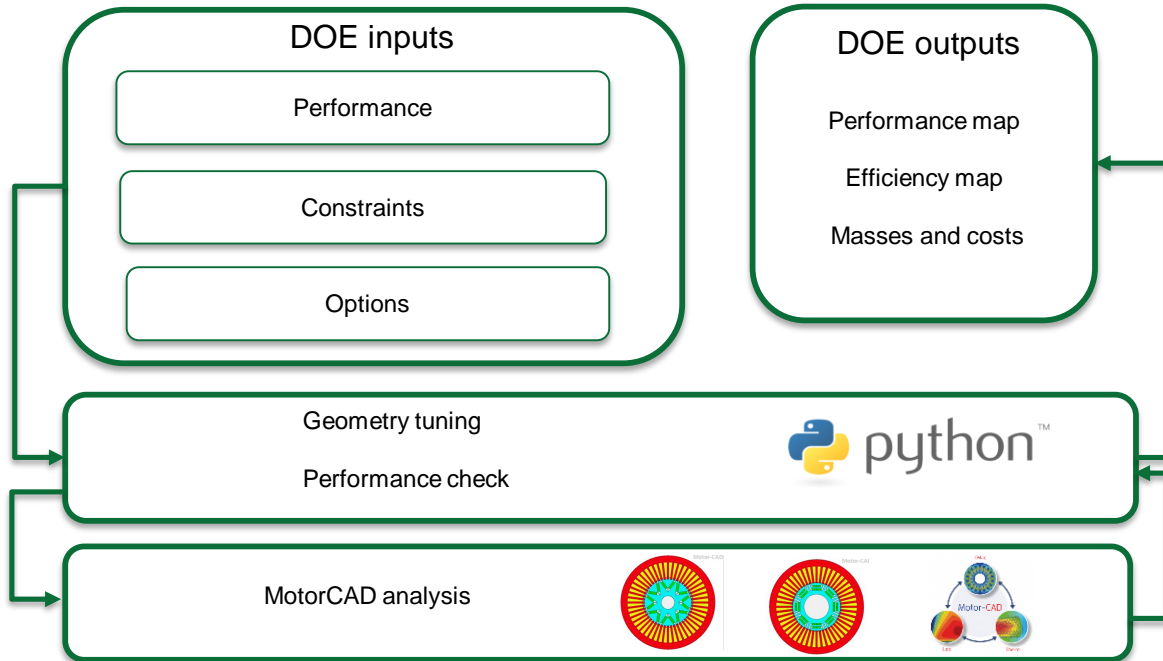


What is the DSD process?

1,000s of powertrain variants

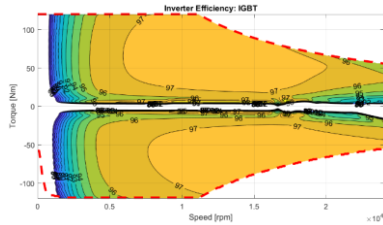




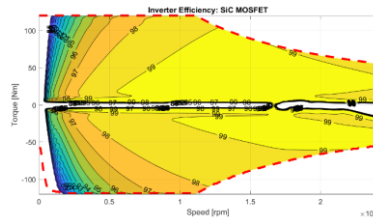


Inverter modelling

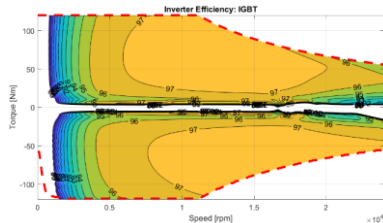
IGBT



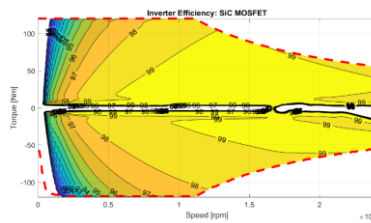
Silicon Carbide (SiC)



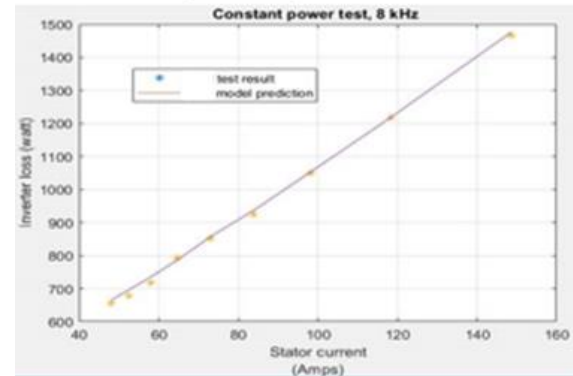
IGBT



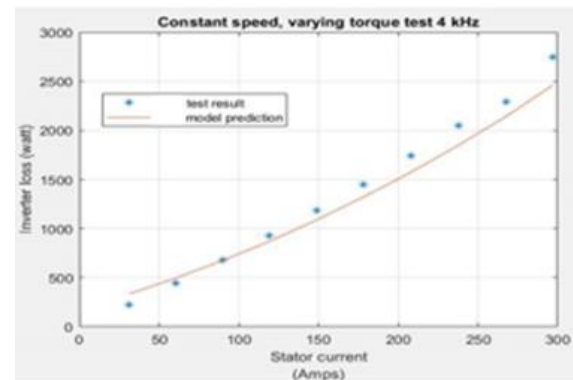
Silicon Carbide (SiC)



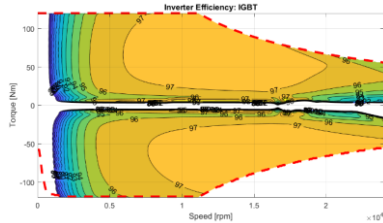
Test 1



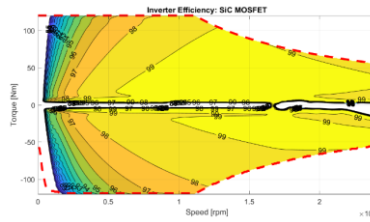
Test 6



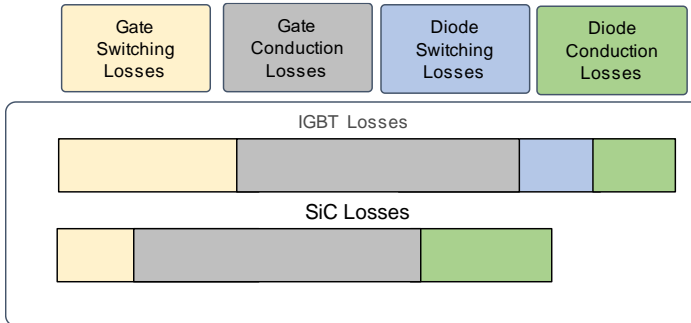
IGBT



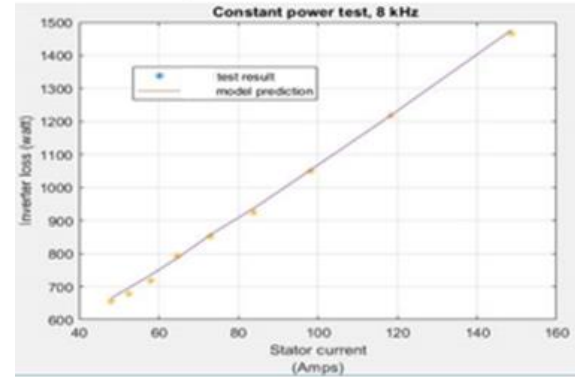
Silicon Carbide (SiC)



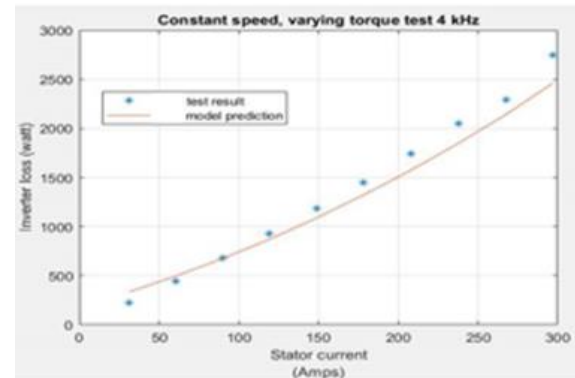
Losses



Test 1



Test 6



Transmission modelling

2-Stage



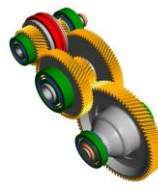
3-Stage



Planetary



Multi-Speed



Transmission modelling

2-Stage



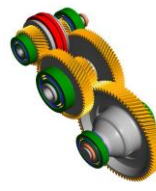
3-Stage



Planetary



Multi-Speed



Losses

Bearing Losses

Loaded

Un-Loaded

Mesh
Losses

Churning
Losses

Seal
Losses

Transmission modelling

2-Stage



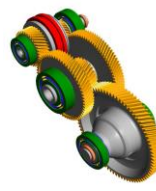
3-Stage



Planetary



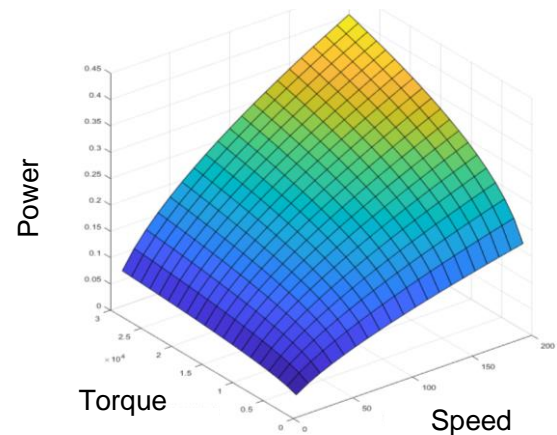
Multi-Speed



Losses



Efficiency map



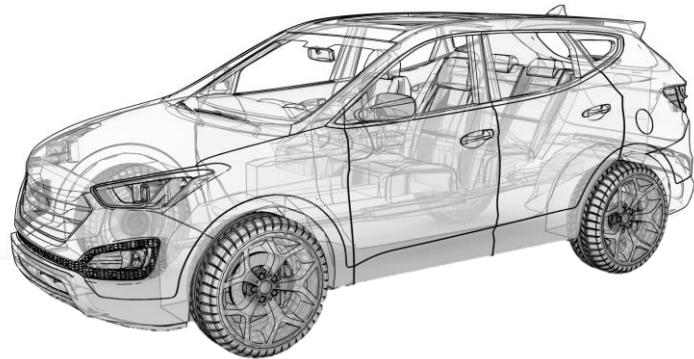
Case study vehicle

Specification

Premium SUV
Pure EV

Performance Targets

Range
Top Speed
Acceleration



Case study vehicle

Specification

Premium SUV
Pure EV

Performance Targets

Range
Top Speed
Acceleration

Transmission Variants

Single speed

2-speeds

Motor Variants

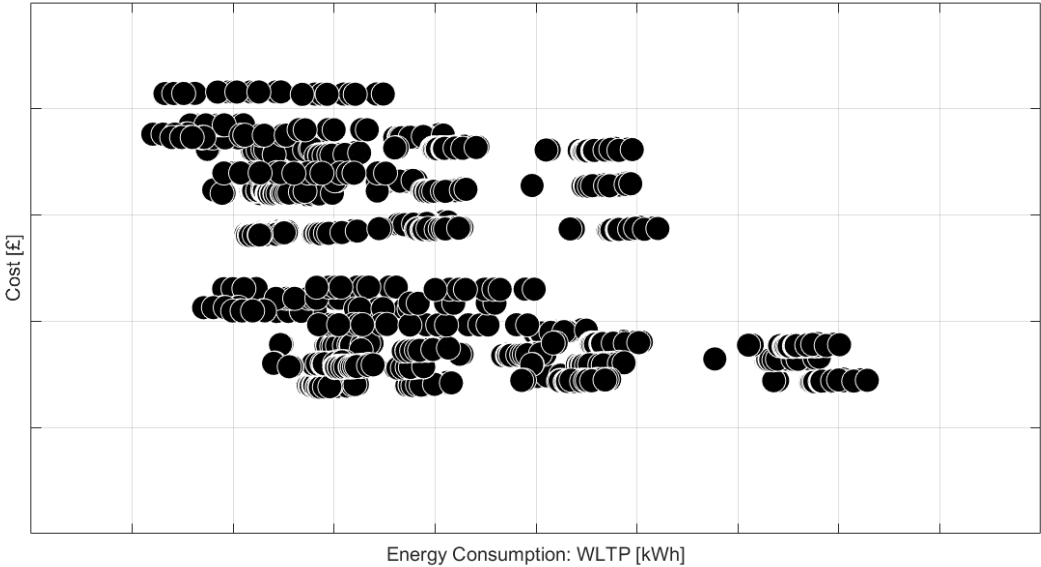
160 kW Fixed
(V shape, U shape)

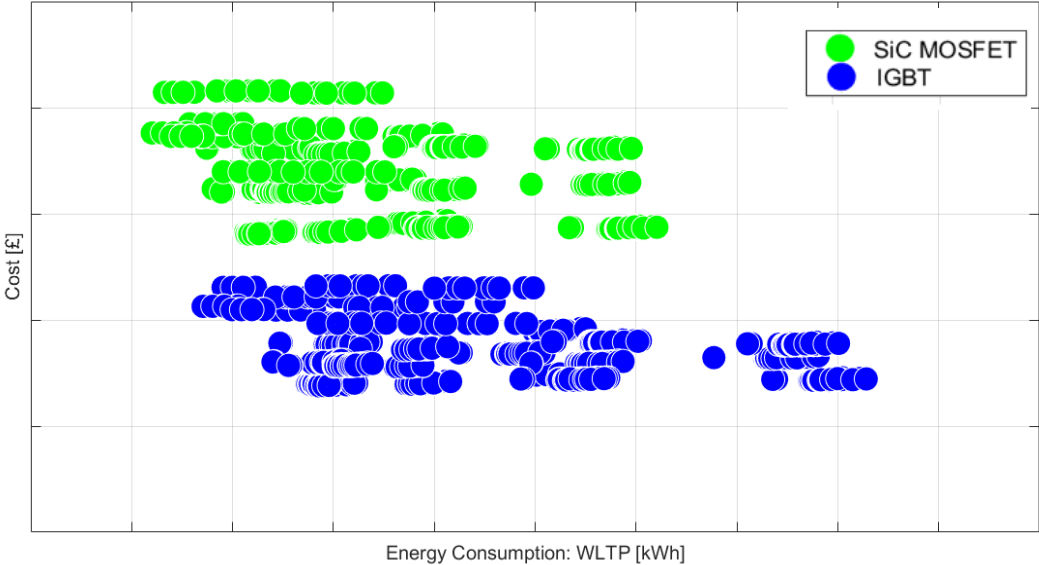
6, 8, 10 poles

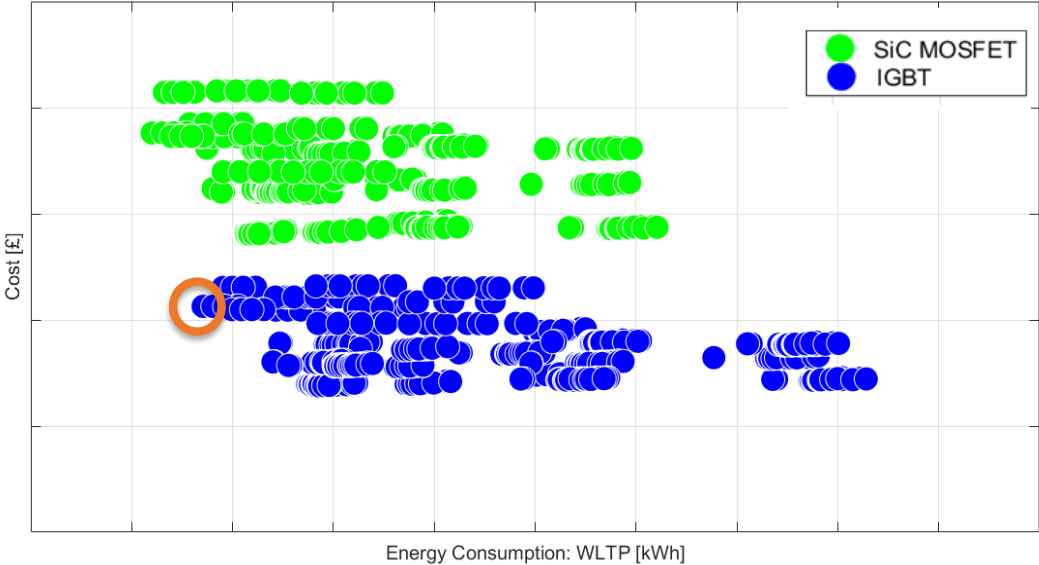
Inverter Variants

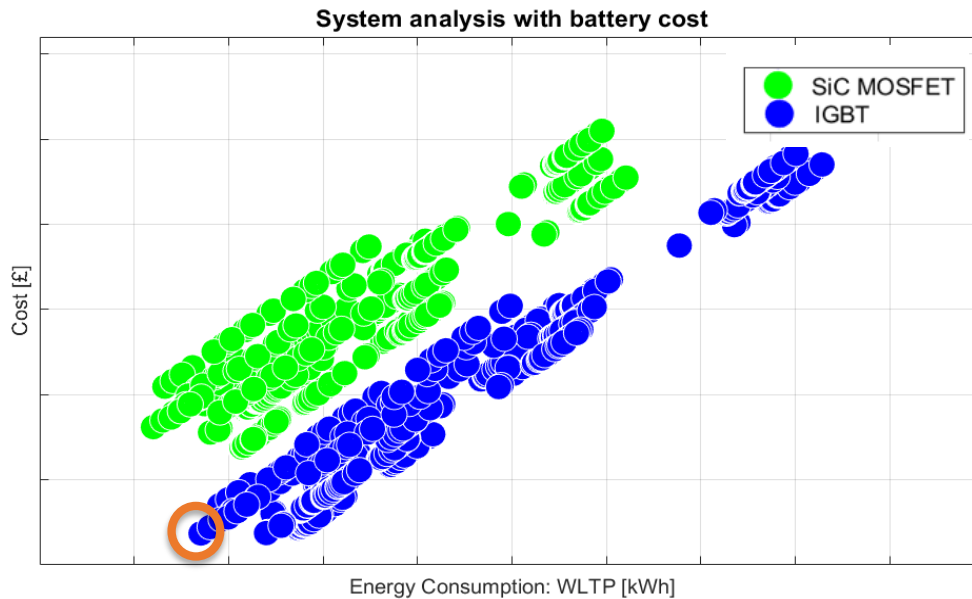
IGBT

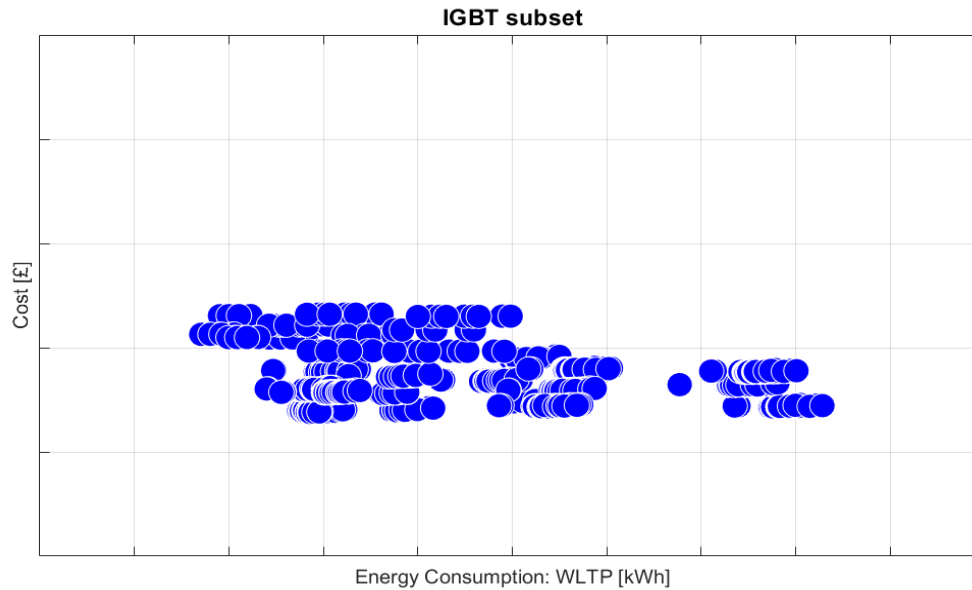
SiC MOSFET

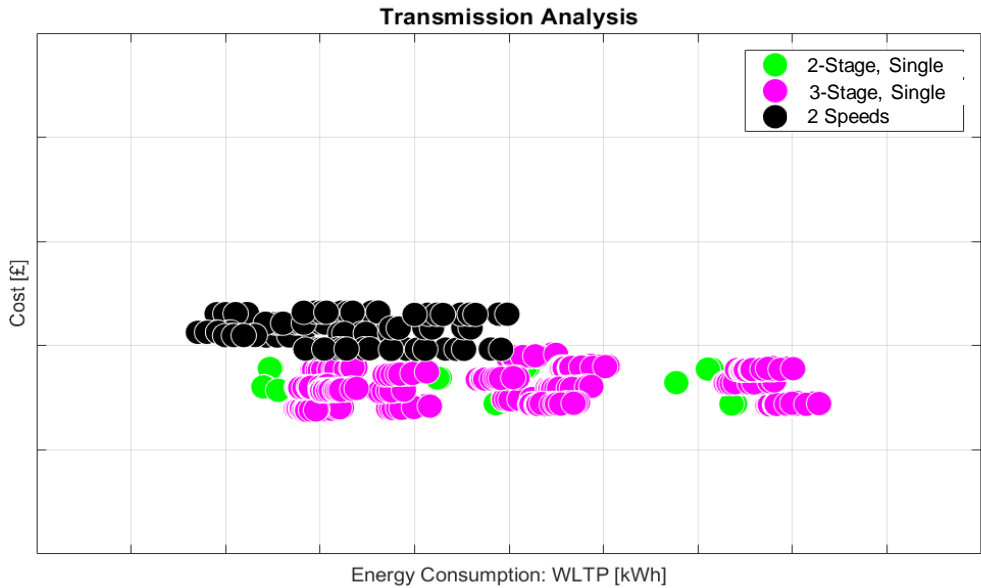


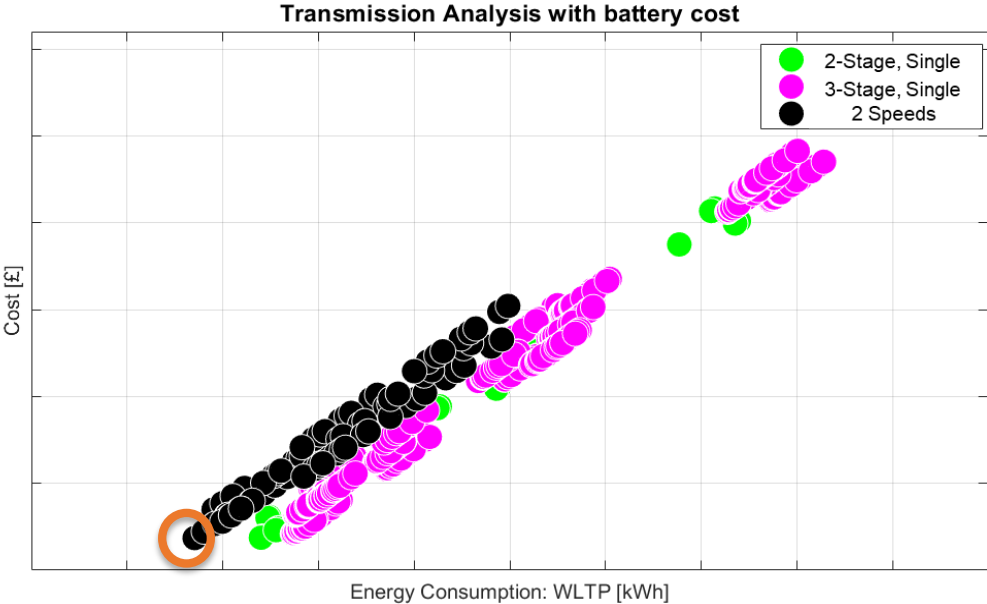


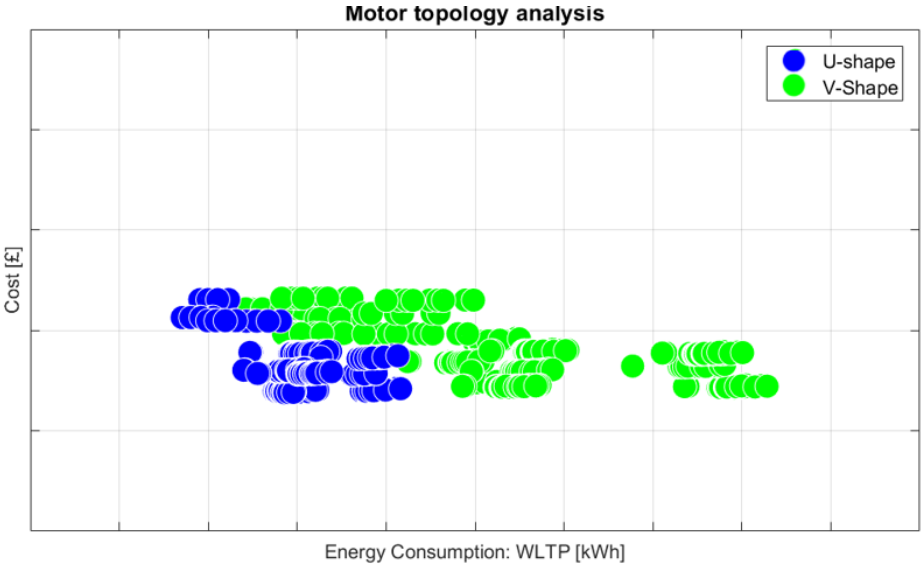


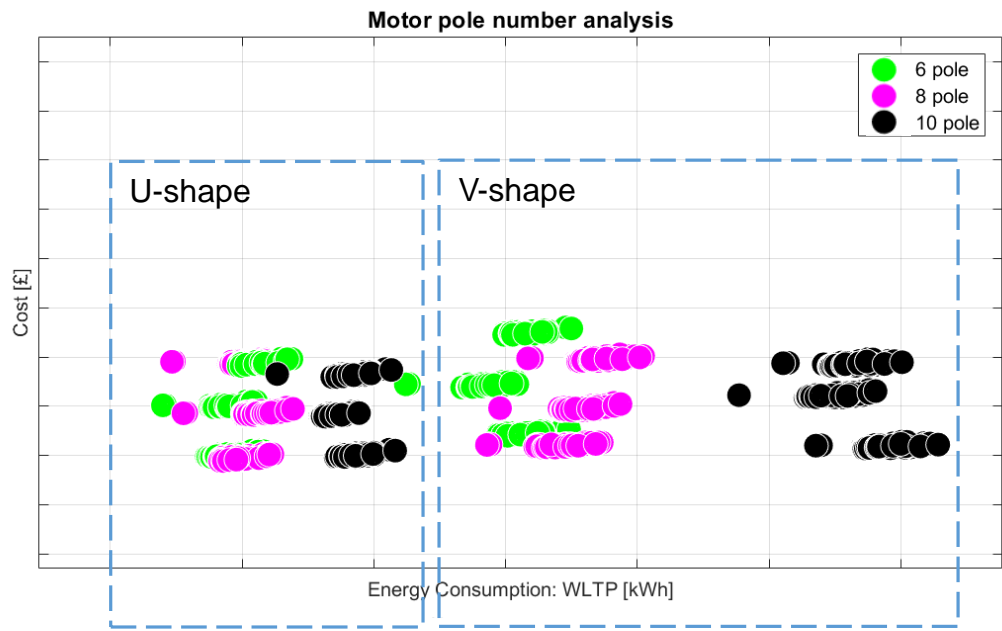


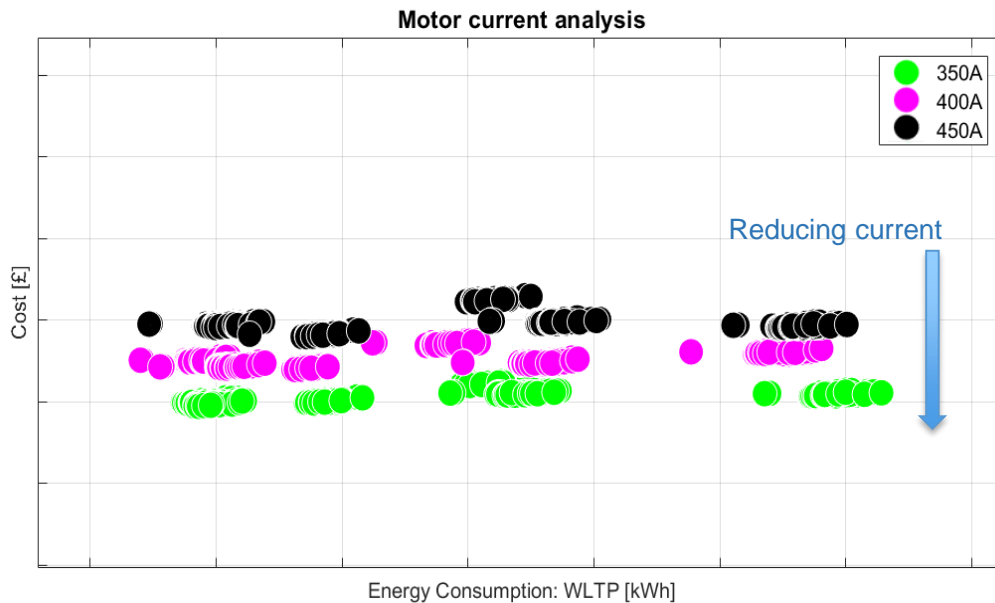


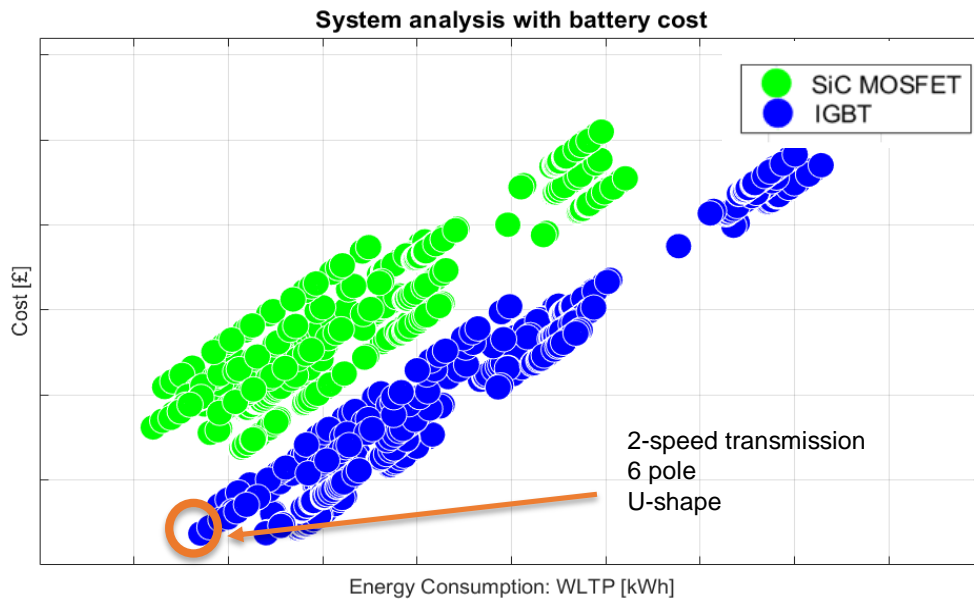




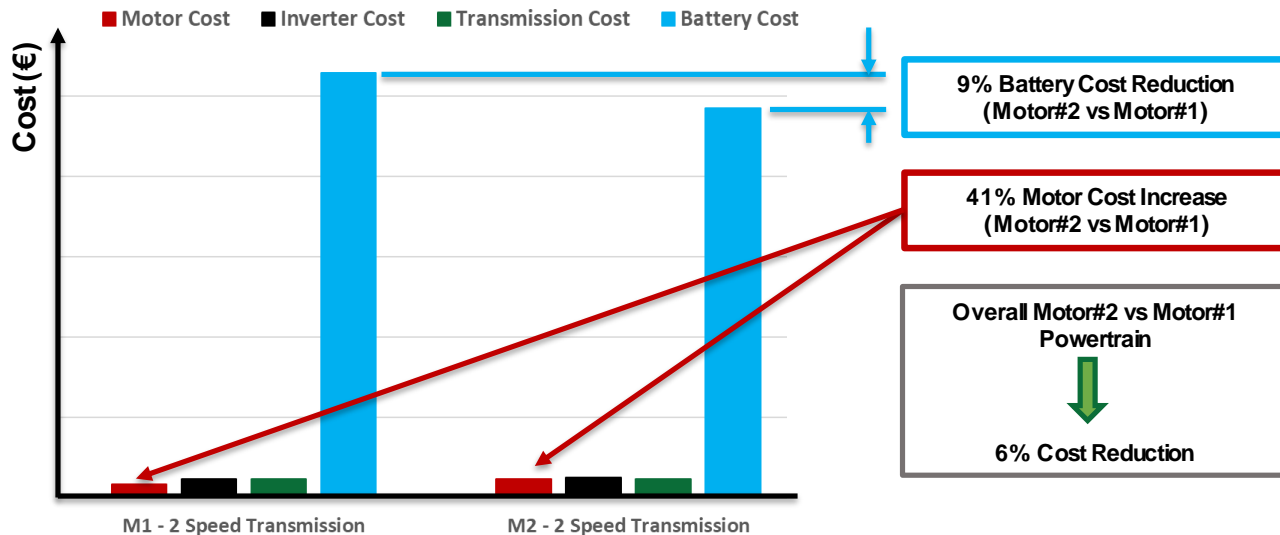








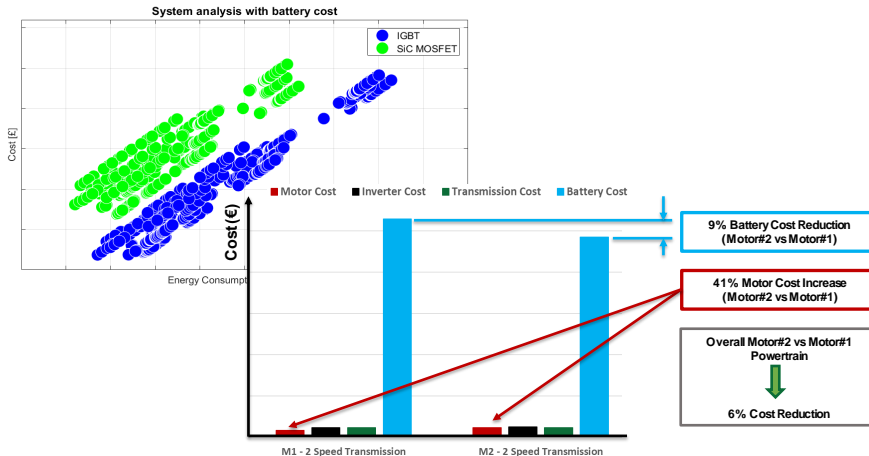
What can this mean in terms of whole propulsion system cost?



An accurate system analysis tool for rapid optimisation of electric / electrified powertrains

- Rapid component model creation
- Design space mapping
- Evaluating complex trade-offs
- Quantifying total system configuration for trade-off analysis and defining lowest cost to achieve vehicle attributes
- Weight cost function to account for different markets and applications

electrified Powertrain Optimisation Process



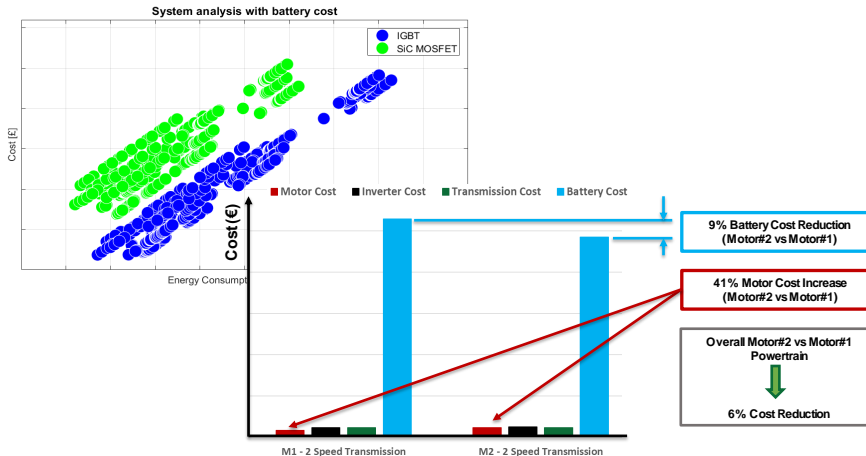
Where next?

- Further variant options
- Hybrid vehicles

An accurate system analysis tool for rapid optimisation of electric / electrified powertrains

- Thank you!
- 고맙습니다

electrified Powertrain Optimisation Process





DRIVE
SYSTEM
DESIGN

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